Chapter 11
Design Principles, Strategies, and Environmental Interaction of Dynamic Envelopes

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Abstract In the era of sustainable development, the building envelope system has gradually become the focus of attention, because of its important function of serving as the separation interface between indoor and outdoor. The dynamic adjustment mechanism of environmental interaction is an effective strategy for buildings to deal with complex external environments. As the dynamic envelope system has technical and aesthetic advantages that form unique space experience and functional adjustment, it provides a new way for building development. With the progress of the times, it will show more abundant prospects. This chapter takes the practical development of the dynamic envelope system as the research object and summarizes the current climate-adaptive design strategies, realization forms, problems, and future trends by sorting out the categories. Finally, combined with the specific practice, the operability application method is proposed, which can provide a reference for the design method of the dynamic envelope system combined with buildings.

Keywords Dynamic envelope · Climate response · Sustainable design · Material construction · Design strategy

11.1 Appearance and Space, Static to Dynamic

In recent years, the issue of building energy consumption has become increasingly prominent. How to adapt the interior of the building to changes in the external environment and reduce energy consumption has become one of the issues that architects focus on. As the climate boundary, today's dynamic envelope system can perceive external information and respond to changes in the surrounding environment through its own adjustment, and gain design autonomy and independence due to technological upgrades in architecture, giving full play to the interface effect.

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The dynamic envelope system of a building, including walls, doors and windows, and roof, refers to an interactive change system that can implement measures such as opening and closing the boundary according to people's needs for adjusting the indoor climate (Moloney, 2011). In 1966, American architect Robert Venturi decomposed architectural issues into two levels: space and skin in Complexity and Contradiction in Architecture, and pointed out that in addition to the limited creation of space, there are infinite and rich possibilities for the creation of skins in architecture (Venturi, 1977). The architect regards the envelope system which is independent of the space more and more importantly, trying to create a two-layer interface that exists at the same time. The inner layer solves the function, while the outer layer solves the form. At the same time, the dynamic boundary of the outer layer makes the interior space of the building no longer isolated from the natural environment.

On the other hand, the rapid development of technical means and communication media has given new meaning to the dynamic envelope system. Due to the dynamic characteristics of the envelope system itself, it gets rid of the fixed image of the original facade, and has unique advantages in terms of space requirements and user experience. With the close integration of mechanical dynamics, parametric design and other fields with architecture, the dynamic envelope system integrates various technical design methods to become an interface for improving building performance. The dynamic environment interaction can become an important fulcrum for architectural mass change and image communication. Buildings are no longer satisfied with the limited space framed by walls, and rely on facades for information dissemination. These make people feel about the building from the inside to the outside, from the whole to the fragments, and from the space to the appearance (Chen & Mo, 2008). The design of a dynamic envelope system that interacts with the environment has gradually become an important focus of architectural design.

11.2 The Value Pursuit of the Dynamic Envelope System

11.2.1 Ecological Value Pursuit: Light, Heat, and Wind Environment

Under the dominant trend of sustainable development needs, building envelope systems are closely related to energy consumption. Like the cell membrane that controls the entry and exit of substances, it controls the entry and exit of natural elements such as indoor and outdoor light, heat, and wind. It is the interface between the building and the environment (Fig. 11.1).

The envelope interface is changed according to the comfort of building users, so that the building integrates into the natural environment, reduces the dependence on the artificial environment, and avoids the energy consumption of the facade during the four seasons. It constitutes a sufficient condition for building energy efficiency, and therefore has become an important architectural design goal. Among the many

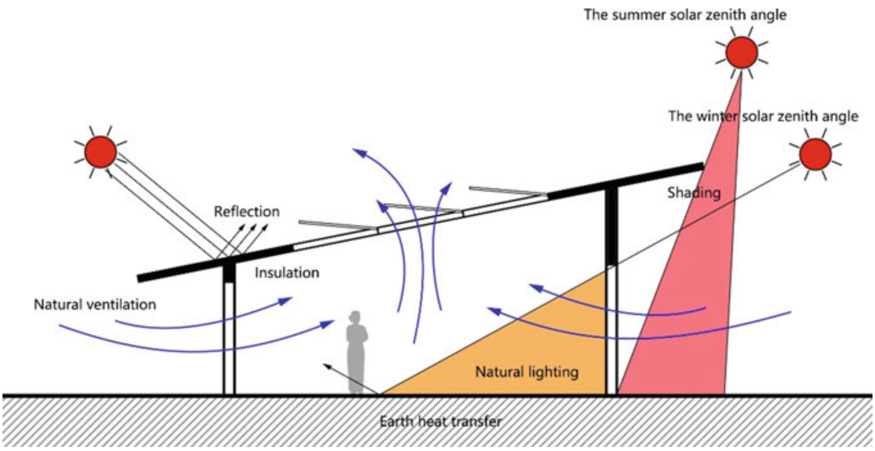


Fig. 11.1 Interaction between the envelope system and the environment

factors that affect the climate, the most decisive factor is the sun's light and heat radiation (Li et al., 2008). In response to the four seasons of the external environment, the interaction requirements inside the building are not fixed, such as the need to introduce sunlight to enhance heat preservation in winter, the need to block sunlight to enhance ventilation in summer (Feng, 2004), and other conflicting conditions. A single design strategy cannot fully satisfy the use or avoidance of natural conditions in different seasons or weather conditions. While the dynamic envelope system that interacts with the environment gets rid of the fixed passive adjustment style and can better exert the climate response advantages to enhance the comfort and energy-saving effect of the building.

For example, in the new office building of the Dutch Charity Lotteries company (Goede Doelen Loterijen) (Fig. 11.2), the green roof composed of many triangular blades can use diffuse reflection to avoid direct glare, guide natural ventilation, and also have the effect of collecting rainwater. The roof spans the original building volume, turning the old courtyard into a sunny Mediterranean square.

11.2.2 Diversified Spatial Adaptability

The dynamic interface will have the opportunity to take advantage of some temporary architectural functions and rely on enclosures to meet diverse spatial needs. For a long time, buildings are often only satisfied with certain specific functional requirements, but with the development of multi-functional space requirements throughout the life cycle, there are higher requirements for buildings in the new era. Dynamic

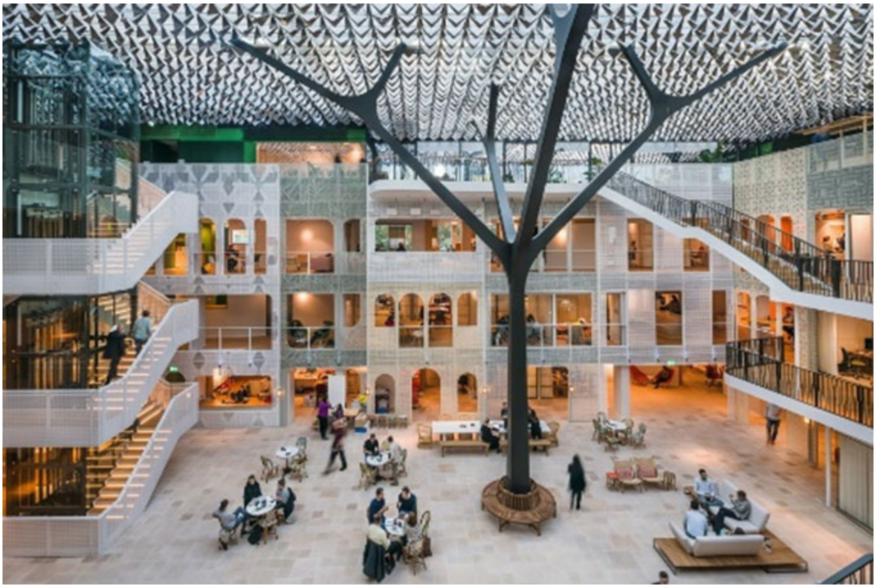


Fig. 11.2 The green roof of the Dutch Charity Lotteries company

buildings can provide conditions for different activities and behaviors by controlling the opening and closing of the shape according to the climate or use conditions (Zuk & Clark, 1970). At this time, the dynamic envelope is generally not an isolated component unit, but a certain volume that constitutes the building. Due to the changing opening and closing of the envelope system, the boundary between indoor and outdoor is blurred, forming different spatial effects.

The typical method of using dynamic envelopes to form a variable space is to form a semi-outdoor space by moving the skin. For example, "The Shed" (Fig. 11.3) located in Hudson Yards in the United States has the same dynamic principles as the sliding house in Suffolk, England many years ago. The telescoping outer shell of "The Shed" is separated from the base building and glides along the rail to form an iconic space for large-scale performances and exhibitions. The unfolded building volume increases the interior area by 1,600 square meters compared to the original. The designed kinetic system comprises a sled drive and bogie wheels guided by the rails to realize the changing process of retraction and extension. Besides, the energy-saving design scheme adopted by "The Shed", through the radiant heating system, variable forced air heating and cooling system, provides the most efficient environmental regulation for the extended part of the outer skin (Eric Baldwin 2019).

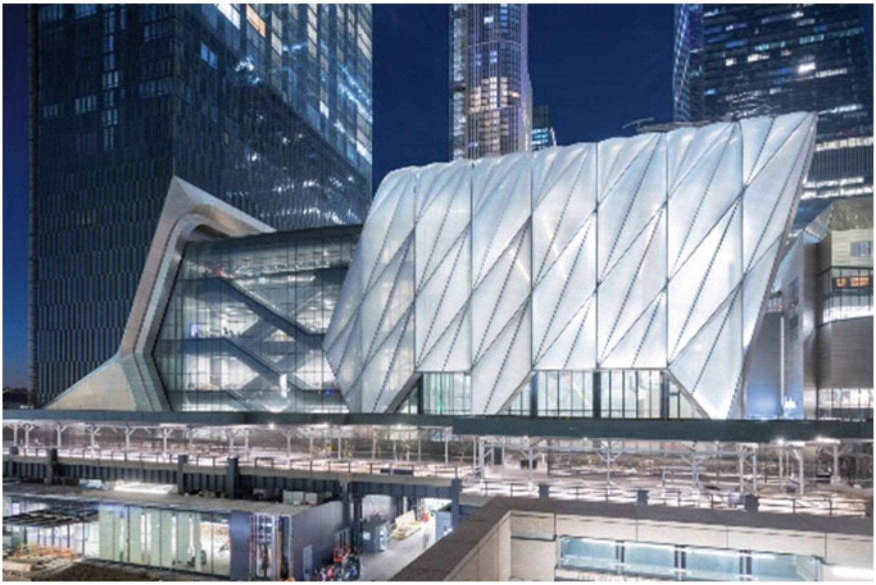


Fig. 11.3 The Shed

11.2.3 Improved Aesthetic Feeling

One of the goals of the dynamic enclosure system is to enhance aesthetics. The design puts beauty above the adjustment of environmental factors such as light and heat. The form of the envelope structure is relatively obvious, and it is mostly two independent logics with the inner space, which breaks away from the modern rule of "form follows function".

The dynamic envelope system itself has unique aesthetic characteristics (Wang, 2011), which conforms to the dynamic aesthetic characteristics of the crowd (people tend to notice moving objects more easily). Compared with the single form of the general building volume, the envelope forms can be rich and diverse, showing the complexity of change and the beauty of order. Some pay attention to dynamic changes and positive interactions with human senses. The opening and closing of the interface satisfy people's different psychology of being close to or isolated from nature. Just as the American ecological psychologist Theodore Roszak put forward the concept of ecological subconsciousness in his book "The Voice of the Earth", he believes that people have an instinct to love life (Biophilia) (Roszak, 1992). In the architectural practice of recent years, the closeness and the interaction between man and nature have become more and more concerned.

In addition, the use of lights, colors, textures, etc. in the envelope brings users a unique sensory experience due to the rich and variable effects they form. For example, in the Shanghai Bund Finance Center, the dancing facade refers to the traditional Chinese bridal crown decoration. Decorative pillars of different lengths can move

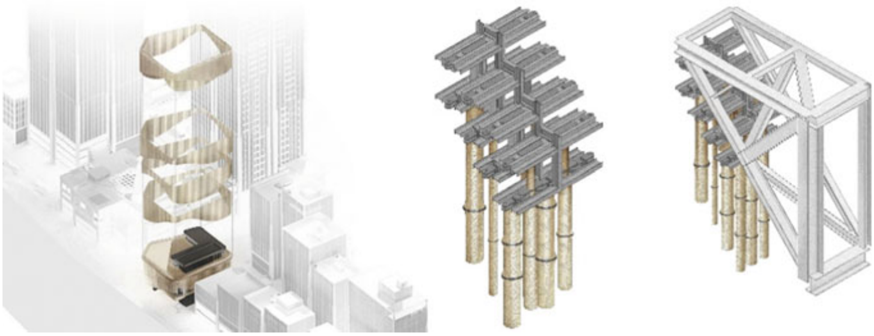


Fig. 11.4 Facade of Shanghai Bund Finance Center

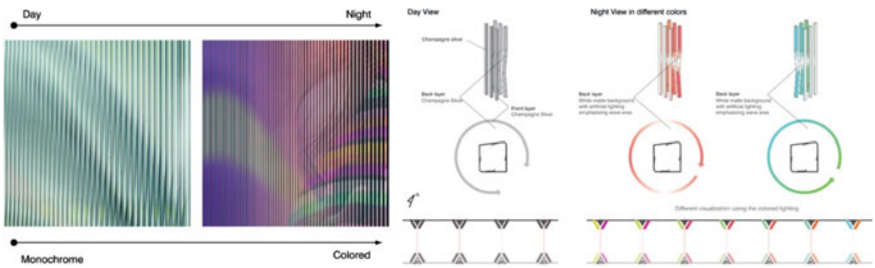


Fig. 11.5 Optical illusion appearance of Galleria Centercity department store

independently. The appearance of the building presents different transparency and visual effects according to the rotation and overlap of the interfaces at various levels (Fig. 11.4). South Korea's Galleria Centercity Department Store adopts a double-layer multimedia facade on the exterior of the building, that is, the vertical sides on the glass shell and the inclined sides of the inner skin (UNStudio, 2019). This combination forms a wave-like optical illusion effect, which will change according to the difference in viewing position (Fig. 11.5).

11.3 The Changing Principle of the Dynamic Envelope System

The famous 20th-century scholar Gilles Deleuze reflected in his book "The Fold: Leibniz and the Baroque" that when the surface of a building has the dual characteristics of construction and material, the surface can replace the spatial structure and become the dominant of the building, and the dominant of space and time (Deleuze, 1993). Based on this, the following section divides the dynamic principle of building envelope into three types: variable construction, variable material, and variable construction combined with materials (Payne & Firefly, 2013).

11.3.1 Variable Construction Depending on the Mechanical Device

The variable construction in envelope systems refers to relying on other external energy sources such as motors or manual drives to change the spatial position of the unit through a mechanical system, and respond to the external environment accordingly. There are no special requirements for the material properties of the components, and according to the principle of change (Moloney, 2011), it can be subdivided into basic motion forms of rotation, sliding, and compound motion forms, such as folding, telescoping, etc.

(1) Rotation. As a common dynamic change mode, due to the uniform rules of the variable unit, most of the components are uniformly repeated geometric shapes. Rotation can obtain more varied effects according to different angles without changing the shape of the unit. The way of change can be around the central axis, around a certain unit frame, etc. (Fig. 11.6), to form a kaleidoscope-like facade visual effect, and interactively adjusts environmental factors such as light, heat, and ventilation.

(2) Sliding. The slide rail, which usually contains a two-dimensional plane, is a more direct way of opening and closing the interface. In order to reduce the influence of gravity on components, most of them move in the horizontal direction, and interface units are often overlapped or complemented, so as to achieve the requirements for versatility in lighting, ventilation, and functional space.

(3) Folding. The system is usually composed of simple panel components, which are controlled by telescopic rods, and the shape changes through unfolding

Fig. 11.6 Schematic diagram of rotation principle of Hazza Bin Zayed stadium envelope system

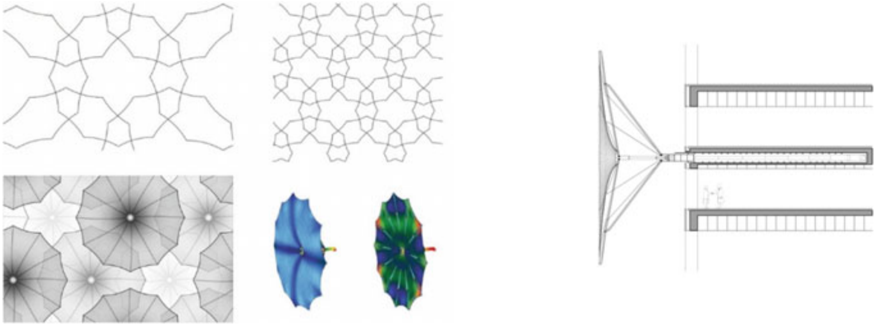


Fig. 11.7 Dynamic envelope unit construction of the Conjoined Media Towers

and stacking to realize the opening and closing for the control of natural light and ventilation systems. Because its change method is similar to the principle of folding doors, it is sometimes used to meet the functional requirements of building internal space expansion and flexible division (Miao & Feng, 2016).

(4) Stretching. It can be understood as a composite form of sliding and folding, which is widely used. This principle usually changes in a three-dimensional space. For example, the Conjoined Media Towers design scheme for the "unending sunlight" in the Middle East. Contrary to the traditional method of retracting umbrellas, the retractable sunshade envelope system passes outwards. The driving force retracts the umbrella surface, and then the whole is hidden in the corresponding structure along with the umbrella handle (Fig. 11.7).

11.3.2 Variable Materials Based on Their Own Characteristics

The material-variable refers to the interaction between the dynamic envelope system and the environment based on the characteristics of the material itself. Building regulation in this case often does not require external energy sources such as motors to perform work, but it is usually not as precise and controllable as the construction method.

The vertical planting of the building is a typical variable material. Plants are in a state of change due to their own growth characteristics. In summer, plants grow luxuriantly, which can bring good shading effect, and the transpiration and photosynthesis of plants can effectively reduce the surrounding environment temperature and improve the environmental quality. In winter, the leaves of plants are fallen, so that the building can be fully lighted, and the different types of plants give the facade a vibrant scene (López et al., 2015).

Another example is that under the action of a lower driving voltage or current applied to electrochromic materials, the optical properties (reflectivity, transmittance, absorptivity, etc.) will undergo stable and reversible color changes (Smart glass [EB &

OL], 2020). The electrochromic smart glass made from it has the adjustability of light absorption and transmission. Selectively absorb or reflect external heat radiation and internal heat diffusion, reduce a large amount of energy that the building must consume in summer cooling and winter heating, and at the same time play an active role in regulating the degree of natural light.

11.3.3 Combination of Variable Construction and Material

It not only uses the characteristics of the material itself but also adopts a structural method to form a dynamic envelope system that is driven by energy to generate climate-responsive adjustments. In the construction method, the appropriate change method should be selected according to the value pursuit. In the component materials selection, it should be durable and energy-saving or use renewable energy. Because it combines the advantages of the above two response methods, it has a wide range of application prospects.

As mentioned above in "The Shed", the ETFE material used can realize the adjustment of the building environment by means of lamination and so on (Cui & Miao, 2014). The combination with the sliding strategy enhances the climate response of the extended space and makes the indoor environment more selectively controlled. Meanwhile, the energy consumption of equipment is reduced, and the effect of seeking benefits and avoiding harm to the natural environment is achieved.

11.4 Organizational Mode of a Dynamic Envelope Unit

The unit organization mode is related to the aesthetic feeling of the building facade and the way of control. When the unit modules are densely laid on the building surface, it is required that the building shape should not be too complicated, and the units can be changed in groups vertically or horizontally along the floor. In the design process, it is necessary to avoid friction loss, enhance the replaceability of components, and consider the influence of natural factors such as wind.

11.4.1 Unit Form

In the selection of unit form, regular geometric shapes are often adopted due to factors such as cost and construction. The tessellations (Wikipedia, 2020), which have been studied as early as the era of Pythagoras, can interpret this well.

For example, using a single regular polygon to fill the plane:

The sum of the interior angles of a regular n-sided polygon is $(n-2)180°$, and the degree of each interior angle is $(n-2)180°/n$. When it meets the dense paving

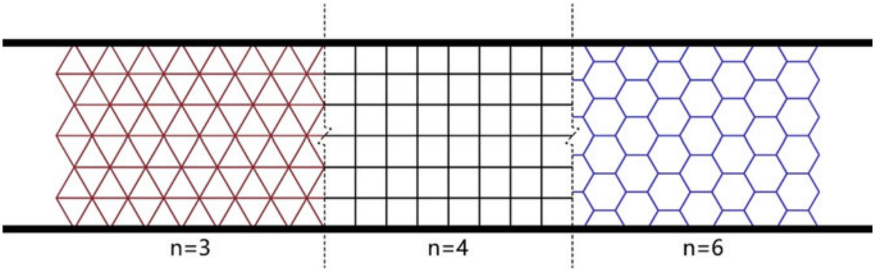


Fig. 11.8 Different unit form with the tessellation principle

condition, there is a positive integer x, which satisfies the equation $x(n-2)\ 180°/n = 360°$.

$$\text{Get } n = 2 + 4/(x - 2)$$

Since n is a positive integer, $x = 3, 4, 6$, corresponding to $n = 6, 4, 3$.

Therefore, except for irregular unit geometries, these methods can achieve complete tiling on the plane. In reality, single triangles, rectangles and hexagons have also become the choice of most dynamic building envelope systems (Fig. 11.8). The regular modular unit method can reduce the cost, is easy to construct, and is conducive to the aesthetics of the facade.

11.4.2 Scale Division

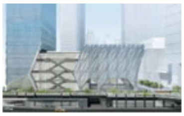
Judging from the current practice of the dynamic envelope system, the unit size is usually selected according to the principle of change and the size of the building facade. In addition, the needs of production, transportation and subsequent maintenance and replacement should also be considered. The floor height of the building is mostly equal to or an integral multiple of the height of the facade dynamic unit, so as to facilitate installation and allow users to control independently according to the floor.

11.5 Design Strategy of Dynamic Envelope Systems

In the design process of the dynamic envelope system, the unit can be set to a regular geometric form, and the changing principles such as rotation and sliding can be applied, or new material properties can be actively explored (Table 11.1).

In practice, we divide the building envelope systems into three types according to different locations: facade interface, roof interface and atrium interface. The next part

Table 11.1 Environmental interaction design elements of dynamic envelope systems

Project name	Project picture	Value pursuit	Changing principle	Specific strategy
Galleria Centercity department store		Aesthetic feeling	Material	Optical illusion material
Shanghai Bund Finance Center		Aesthetic feeling	Construction	Sliding
The shed		Spatial adaptability	Construction and material	ETFE material and sliding
Residential in Suffolk, England		Spatial adaptability	Construction	Sliding
Hazza Bin Zayed stadium		Shading	Construction	Rotation
Kiefer technic showroom		Lighting, shading	Construction	Folding
Conjoined Media Towers		Ventilation, shading	Construction	Stretching

of the article will discuss the three types of dynamic envelope patterns, each of which is detailed with the engineering practice that the author participated in as an example, and each of which is different in the value pursuits and changing strategies, in order to conduct targeted research on the design strategy of environmental interaction.

11.5.1 *Rotating Roof Interface Based on the Pursuit of Ventilation and Shading*

In the project of a green building competition in Changzhou, Jiangsu Province that the author participated in, in view of the climate characteristics of the hot-summer and cold-winter zone, the natural ventilation of the building becomes the design focus. The design strategy applies dynamic envelopes to the fifth facade of the building (Fig. 11.9), using the principle of rotating mechanical construction to achieve interaction with the environment.

The design strategy places the roofs on both sides perpendicular to the solar zenith angle in winter and summer. In terms of the shape and scale of the unit, in accordance with the principles of compactness, reliability, and economy, an isosceles triangle with a minimum side length of 1.2 m is selected as the basic unit module. Taking the vertical line where the unit's vertical center is located as the axis of rotation, it opens and closes in different amplitudes according to the changes in natural light, thereby creating suitable lighting conditions for the interior (Fig. 11.10). The independent closed office space inside the building reduces the indoor heat load in summer and the penetration of cold wind in winter due to the "protective umbrella" function of the roof interface.

The triangular unit cell is combined with the thin-film photovoltaic system (Fig. 11.11), and the angle is rotated according to the light intensity in different seasons. In the high-temperature season, the angle with the highest solar power generation efficiency is selected, taking into account the sunshade (Elghazi & Mahmoud, 2016). In the low-temperature season, the direct glare is reduced while satisfying indoor lighting. In addition, the opening of the roof skylight forms the vertical through space inside the building, which enhances the effect of buoyancy-driven

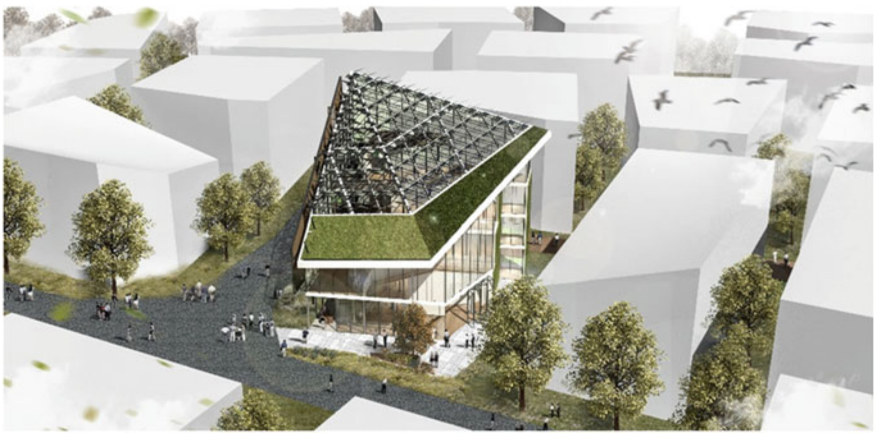


Fig. 11.9 Bird's eye view of the design plan

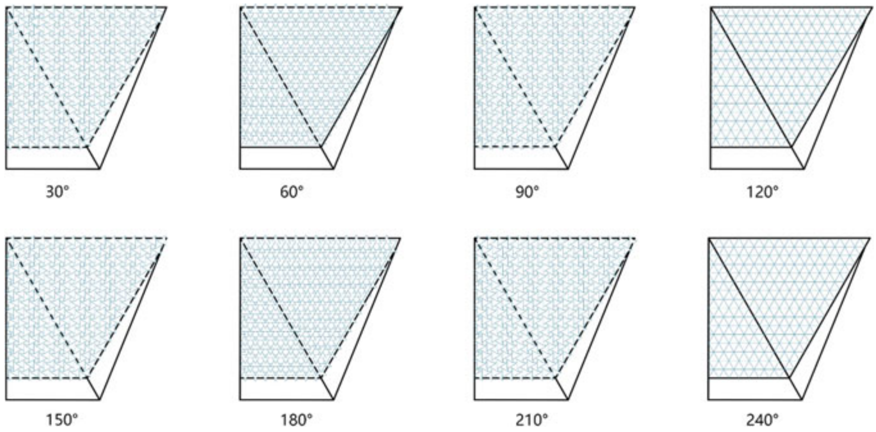


Fig. 11.10 Different rotation angles of dynamic roof units

ventilation. And use software to simulate and verify the effect of different rotation angles on indoor lighting and natural ventilation, and find the optimal set of choices (Figs. 11.12, 11.13 and 11.14).

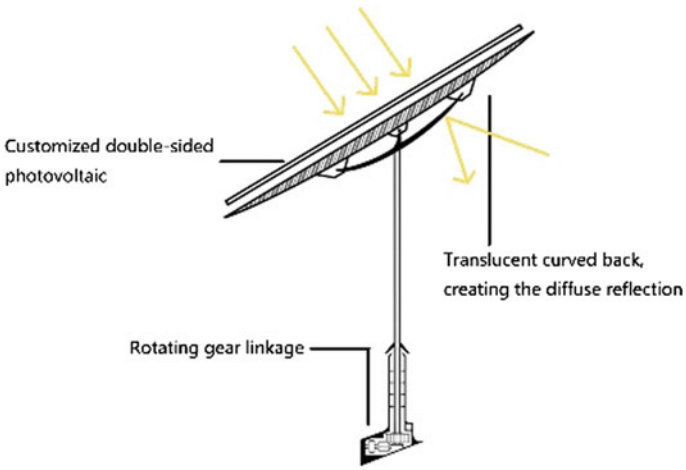


Fig. 11.11 Unit structure design

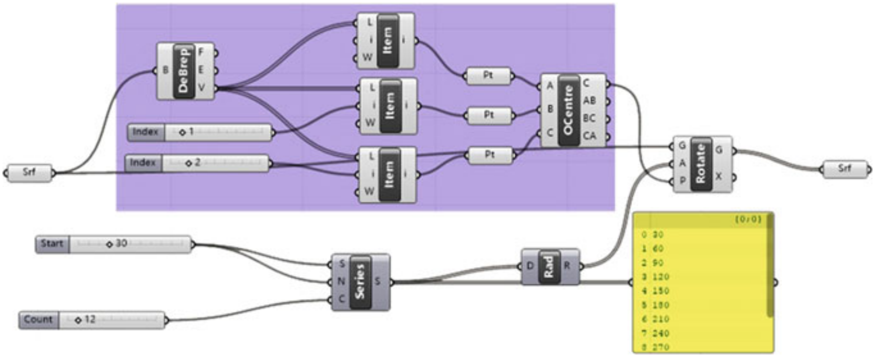


Fig. 11.12 The unit rotates at different angles under the control of Grasshopper

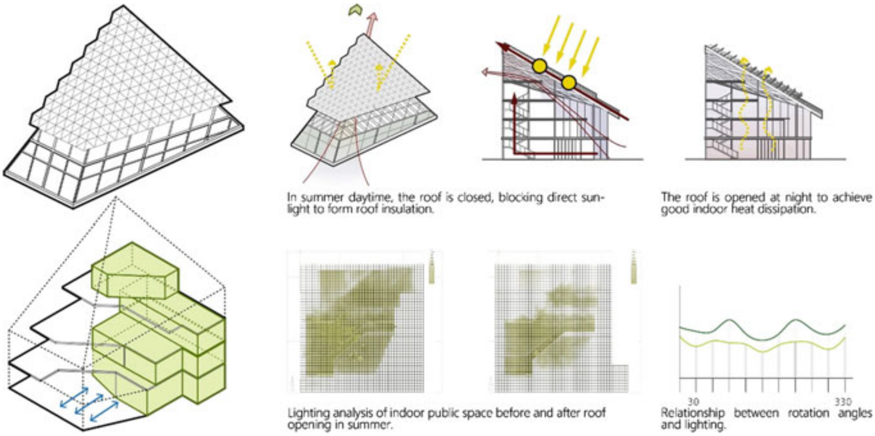


Fig. 11.13 Analysis of summer environmental interaction mode

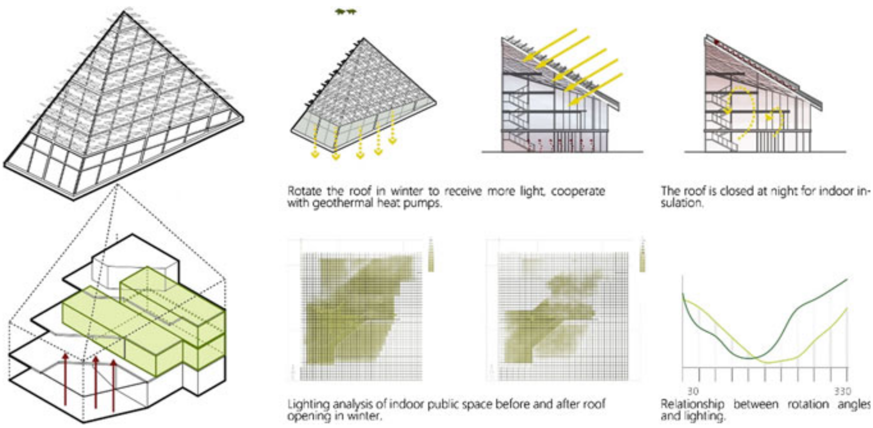


Fig. 11.14 Analysis of winter environmental interaction mode

11.5.2 Folding Facade Interface Based on the Pursuit of Shading

The Miura fold is a folding technology invented by Kōryō Miura, an honorary professor of structural engineering at the University of Tokyo, Japan. This technology is to unfold the items by opening the diagonal ends, and pushing them in the reverse direction when they are contracted, so as to realize the rapid expansion and stacking of materials and the most intensive storage space (Fig. 11.15).

The author takes this as a prototype to design the dynamic building envelope system that interacts with the environment. A high-rise hollow office building is selected, and the proposed column span is 8.0 m and the story height is 3.2 m. Solar photovoltaic panels are selected as the material for the upward part, which collects the electricity generated by the facade and has the effect of shading. Lightweight1 solar panels are selected for the downward part to meet the effects of light transmission, ventilation and heat insulation (Fig. 11.16).

From the formula for the effective use of photovoltaic panels, it can be seen that the larger Rα, the greater the area of the projection surface, and the higher the utilization efficiency of photovoltaic panels. And the utilization efficiency has nothing to do with the edge length. The angle $\alpha = 60°$ of the rhombus unit is selected comprehensively, and β is combined with the formula to select the best choice for each season (Fig. 11.17).

$$f(\beta) = x^2 \sin\alpha * k;\, k = \frac{\cot\beta * \cos\varphi + \sin\varphi}{\sqrt{1 + \cot^2\left(\arccos\frac{\cos\alpha}{\cos\beta}\right) + \cot^2\beta}}$$

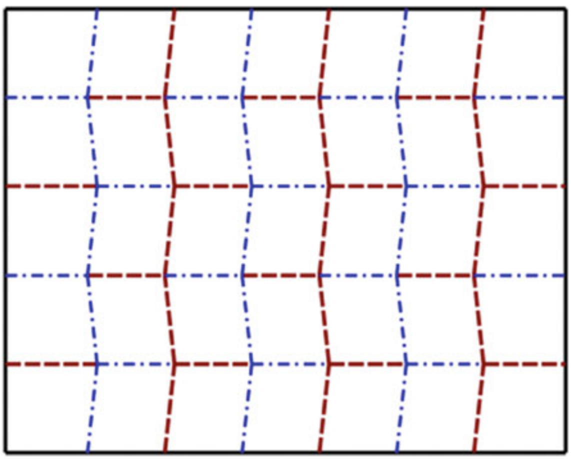


Fig. 11.15 Miura fold principle (Wikipedia, 2020)

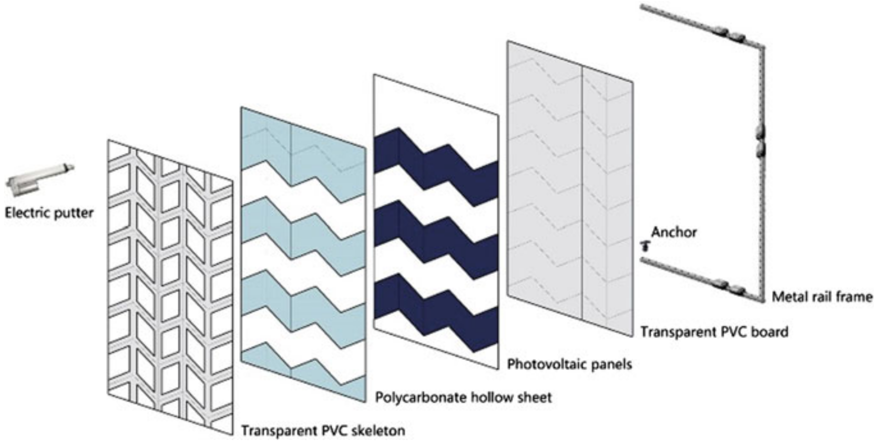


Fig. 11.16 Material selection and connection of double-layer envelope system

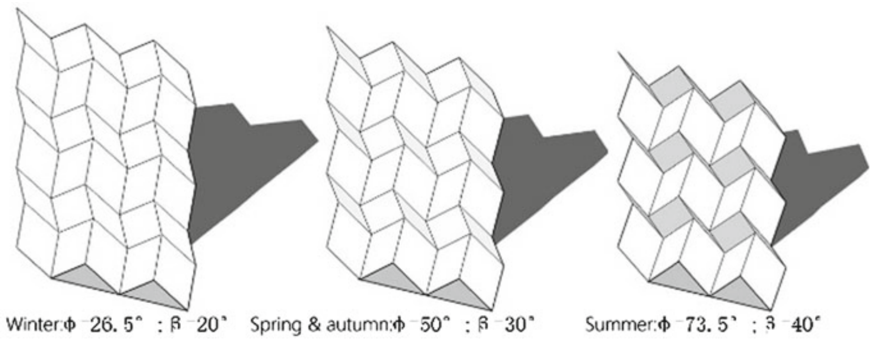


Fig. 11.17 Seasonal changes of a double-layer envelope system

In the above formula: α is the interior angle of the rhombus; β is the angle between the edge length and the vertical direction; x is the side length of the rhombus (Fig. 11.18); φ is the solar zenith angle; f (β) is the projected area of the rhombus on the plane perpendicular to the light; x^2sina is the area of the rhombus; k is the utilization rate of the photovoltaic panel.

Fig. 11.18 Rhombus unit schematic

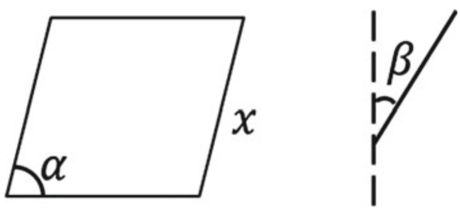


Table 11.2 The relationship between the dynamic envelope system and the season

Solar zenith angle	Angle β	PV panel utilization (%)	Projection length a (cm)	Projection length b (cm)
Winter: 26.5°	19.8°	97.1	37.6	33.9
Summer: 73.5°	39.6°	82.9	30.6	30.3
Spring and autumn: 50°	32.4°	88.6	34.6	33.8

In terms of unit form and scale division, the basic modules are combined into a plane to meet the best effect of the winter solar zenith angle and make the photovoltaic panel reach a larger size. Therefore, the size of each block is set to 4.0 × 3.2 m. According to the data calculation, the projection size of the rhombus module on the vertical plane is a × b = 37.6 × 33.9 cm, and the number of modules can be determined to be 9 × 12. It is calculated from this that the overall facade is reduced to 3.67 × 2.72 m at the optimal angle of photovoltaic in summer (Table 11.2).

This dynamic envelope system uses the changing principle of folding to achieve better matching of solar zenith angles in different seasons and improve the use efficiency of photovoltaic panels. In winter, it is completely closed after being unfolded to the best angle, and the vents are closed, and the "greenhouse effect" formed will further play the role of heat preservation and heat insulation. In summer, when it is reduced to the best angle, it will ventilate on the bottom side, forming a "chimney effect" with the upper gap, strengthening natural ventilation, and at the same time play a certain shading effect.

11.5.3 Sliding Atrium Interface Based on the Pursuit of Spatial Adaptability and Ecology

As a climate exchange space inside and outside the building, the atrium space plays an active role in building energy conservation and improving the indoor environment (Li, 2015). However, the climate control effect of the atrium is often a double-edged sword. While introducing light and ventilation, and using the greenhouse effect, there is also a contradiction between high temperature in summer and large amount of heat dissipation in winter (Table 11.3). The existing atrium has designs that incorporate dynamic devices, such as operable shading facilities set on the top of the atrium or inside and outside the curtain wall (Zhao, et al., 2018). But its function is single, and the amount of sunlight in the atrium can only be changed by changing the angle.

Based on the idea of climate control, this research proposes an innovative spatial interface regulation model. In response to climate change, through its envelope interface-the floor slab, climate regulation is carried out through lifting and lowering adjustments, so that the indoors can achieve the purpose of climate resilience.

Table 11.3 Advantages and disadvantages of climate control in traditional atriums

Climate control	Advantage	Disadvantage
Atrium interface	Natural lighting	Excessive temperature in summer
	Greenhouse effect	Excessive heat dissipation in winter
	Chimney effect	Lack of dynamic adjustment

During the winter day, the floor slab is lowered to the bottom of the atrium, and the greenhouse effect is used to fully absorb the solar radiation heat to increase the temperature of the atrium. At night in the winter, the floor slab is raised to be flush with the second floor, and the floor slab with heat preservation ability is converted into a building roof to reduce heat loss. During the summer day, the floor slab is also raised to be flush with the second floor. It has a shading design to block the excess solar heat and prevent the atrium from overheating. At night in the summer, the floor slab is lowered to the bottom of the atrium, and the vertical through space of the atrium forms the "chimney effect", with the help of windows at the top to form buoyancy-driven ventilation to obtain a good passive cooling effect (Fig. 11.19). Therefore, the dynamic atrium interface integrates multiple functions of climate control such as lighting, shading, heat preservation, and cooling.

At the same time, the floor slab integrates the advantages of lighting and thermal engineering, using aerogel glass with low thermal conductivity, long service life, high light transmittance, and a thin and light structure (Fig. 11.20), adopting the construction method of double-layer 8 mm+ toughened glass, 32 mm+ aerogel particles, and 8 mm toughened glass. This can not only meet the efficient lighting needs of the atrium but also ensure a stable thermal environment in the atrium. In addition, the lifting floor slab can also play the role of barrier-free passage and variable space (Fig. 11.21).

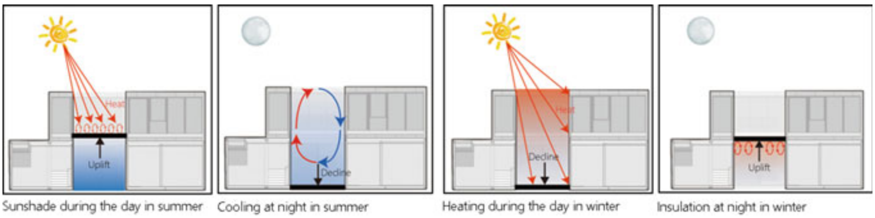


Fig. 11.19 Principles of climate control in the dynamic atrium

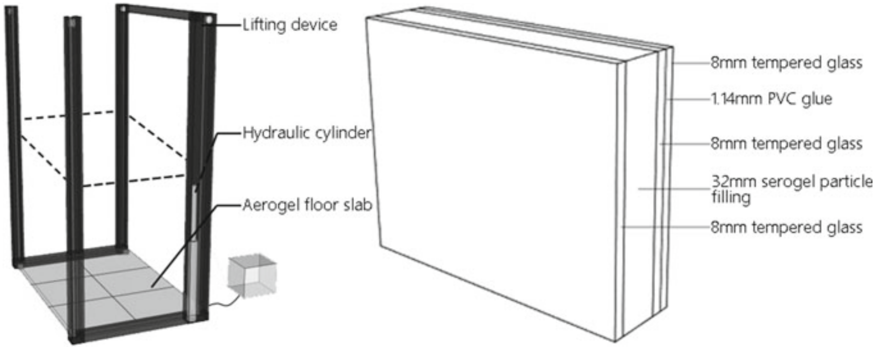


Fig. 11.20 Atrium dynamic system and aerogel floor construction method

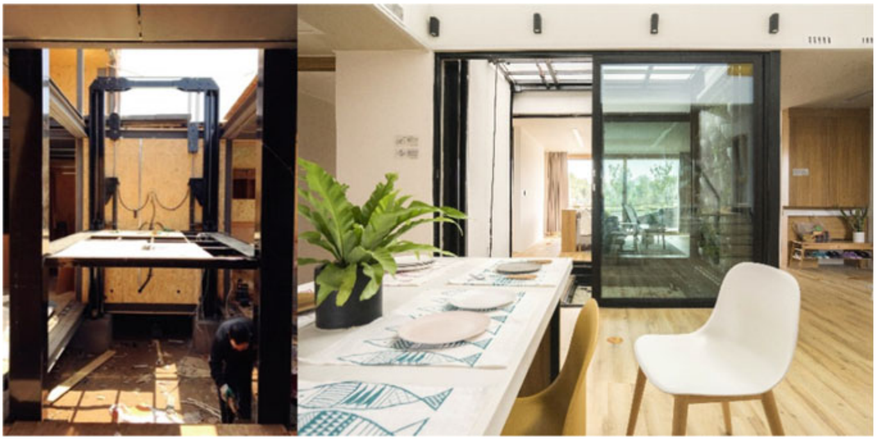


Fig. 11.21 The construction process and actual effect of the dynamic atrium interface

11.6 Conclusion

As important focuses of architectural design, the ecological, spatial adaptability and aesthetic value pursuits of dynamic envelope systems gradually emerge in a large number of architectural practices. As an exchange interface inside and outside the building, its ecological value significance has unlimited potential in the context of today's environment. The realization of the dynamic form of the envelope systems, that is, the principle of change and the way of unit organization, will develop more possibilities, so that the construction design will be more integrated into the building facade. Therefore, regional climate adaptability and adjustability of the facade are achieved.

In the future, explore new breakthroughs from the perspective of sustainability between people and the environment, to better combine manual control, passive control, and automatic control, so that the dynamic envelope system has more adjustability. With the improvement of intelligent control technology, new materials, and innovative construction practices, the problems of energy drive and maintenance, and renewal are bound to be solved. The dynamic envelope system of environmental interaction will be widely used in a variety of building types under different climatic conditions.

Notes

1. It was first proposed by Louis Sullivan, a modernist architect of the Chicago School, in “The Tall Office Building Artistically Considered”, with the original text “That form ever follows function. This is the law.”
2. Theodore Roszak. The Voice of the Earth [M]. New York: Simon & Schuster, 1992.
3. “Biophilia” refers to people’s natural and inherent emotional connection with other people and creatures.
4. Optical illusions, refer to judgments and perceptions that are differentiated from objective reality when people observe objects based on psychological factors such as empiricism or false references through geometric arrangements and the laws of visual imaging. The geometric optical illusion phenomenon is the most common.
5. The tessellations refers to the non-overlapping and gap-free merging of one or several polygons in the same plane, which satisfies the sum of the internal angles of all common vertices to be 360°. Tessellations can be divided into periodic and non-periodic types.
6. The chimney effect, or stack effect, refers to the strong convective ventilation of indoor air along the vertical space inside the building, using the temperature and density differences formed at different heights. The intensity of the chimney effect is related to the vertical height and the temperature difference in the space. The upper part of the building is equipped with exhaust vents to exhaust the dirty hot air from the room, while the fresh outdoor cold air is sucked in from the bottom, thus creating a comfortable and healthy indoor environment.

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